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Data-Driven Nonuniform Subsampling for Computation-Free Compressive Information Acquisition

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Background

The emergent Internet-of-Things (IoT) data explosion will inevitably exert a tremendous data transmission burden onto the wireless edge networks, which are often low-power wide-area networks (LPWAN) with very limited bandwidth. Thus, improving the bandwidth efficiency of wireless edge networks will be of great importance. In addition, the energy efficiency of sensing and computing on IoT sensors or devices is becoming an increasingly critical concern due to the limited battery capacity that can fit into small form factors. As most IoT sensors are used to sample signals at a low frequency (<1KHz), the energy efficiency of such systems is dominated by the energy consumption of radio frequency (RF) transceivers for wireless communication rather than analog-to-digital converters (ADCs). For instance, the state-of-the-art radio transmitters for bio-sensing applications exhibit energy cost in the nJ/bit range while ADCs only consume 10pJ/bit at most. Hence, a generic on-sensor data dimensionality reduction solution for reducing data size for wireless transmission is crucial to improving the bandwidth efficiency of wireless edge networks and the energy efficiency of IoT sensors.

Invention Description

Researchers at Arizona State University have developed a new selective sensing framework that adopts the novel concept of data-driven nonuniform subsampling for acquiring signal information at significantly reduced dimensionality in a computation-free fashion. Specifically, selective sensing intelligently selects the few entries of a signal vector that are most informative to a subsequent reconstruction or inference task based on an optimized selection index vector informed by training data. Since no computation is needed for any form of data encoding, the computational complexity of the selective sensing operator is simply O(1), providing a viable and cost-effective solution for on-sensor data dimensionality reduction, especially for highly resource-constrained IoT sensors or devices.

Selective sensing adopts a co-optimization methodology to co-train a selective sensing operator with a subsequent reconstruction or inference neural network. As the trainable parameters of the sensing operator (the selection index) and the reconstruction or inference neural network are discrete- and continuous-valued, respectively, the co-optimization problem in selective sensing is a mixed discrete-continuous optimization problem that is inherently difficult to solve. In response, an efficient solver method has been devised to transform the mixed discrete-continuous optimization problem into two continuous optimization subproblems, which can then be efficiently solved using gradient-descent-based algorithms. Experiments of image selective sensing empirically show that data-driven nonuniform subsampling can well preserve signal information under the presence of the co-trained reconstruction neural network. Further, the selective sensing framework can outperform the data-driven compressive sensing counterparts by an average of 2.18-3.35 dB PSNR across compression ratios of 4-32x, while fully eliminating the large computational overhead for signal encoding required by conventional compressive sensing approaches.

Potential Applications

- IoT signal compression and decompression
- Biomedical imaging
- LiDAR
- Communication systems
- Video and speech processing

Benefits and Advantages

- Achieves simultaneous sensing and data dimensionality reduction without computation
- Eliminates computational cost at the sensing stage while significantly reducing the data size for transmission and maintaining superior reconstruction or inference performance
- Data-driven nature and generic formulation extend versatility across a wide range of applications

Research Homepage of Professor Fengbo Ren